Do Amerindian communities provide signals to the spatial pattern distribution of trees and palms in Guyana?

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Abstract

This paper examines the proximity of plants that provide critical ecosystem services to indigenous peoples of the Rupununi, Southern Guyana relative to their village centers. We explore the hypothesis that plants of greater importance to indigenous peoples' livelihood activities will be clustered around village centers. Multiple-use plants, species that provide either two or more ecosystem services of non-timber forest products, food for wildlife, and commercial timber, are considered more important than single-use plants, such as those that provide commercial timber alone, because of they provide multiple ecosystem services. Using a linear distance measurement tool developed in python and executed in ArcGIS we measured the average distance of multiple-use plant species to village centers and compared the proximity of multiple-use plants to village centers. Our analysis suggested that plant species that provide wildlife food and commercial timber were closest to Amerindian villages. While these results support the idea that indigenous communities favor forest structure that support their livelihood activities, it also identifies the threat that commercial logging can pose to their livelihood and cultural sustainability.

Keywords: GIS, Amerindians, Multiple-use plants, Guyana, Near-distance analysis, forest structure.

1. Introduction

The influence of Neotropical indigenous peoples on their environment, in particular how their actions shape the nature of the forests within which they live, has long attracted the attention of scholars (e.g. Denevan, 1992; Posey, 1982). Despite the suggestion that indigenous peoples shape the structure of the forests around them to favor the supply of plants for food, medicine and shelter, much of the work done on detecting their presence and influence on historical landscapes has been compiled from oral history (e.g. Goeman, 2008) and archaeological evidence (Kristensen and Davis, 2013).

The results of such work are often used to justify a myriad of applications, including lobbying for lands for indigenous peoples (Pearce and Louis, 008) and protecting their usage areas from commercial exploitation. Plant distribution patterns and how these are shaped by cultural practices of indigenous peoples will provide a stronger rationale for including indigenous lands in payment for ecosystem services (ES) regimes. Yet, using plant distribution for detecting indigenous people's presence within a landscape in an area of study that has not received much attention.

This study draws on the landscapes of the Amerindian peoples of Southern Guyana, primarily the Makushi and Wapishiana Amerindians, to understand whether the distribution of plants upon which they depend upon for traditional purposes provide signals into their presence. The Makushi and Wapishiana Amerindian have lived in the Rupununi region for thousands of years (Plew, 2004) and continue to maintain strong relationships to their forests (Forte, 1996; Read et al. 2010) including for subsistence activities. To examine whether signals of indigenous peoples presence can be observed within the Rupununi landscape, the distribution of multiple-use plants, species of palms and trees that are associated with indigenous peoples livelihood practices is analyzed within a geographical information systems (GIS) environment.

Multiple-use plants, defined as trees and palms whose fruits, barks, leaves, stems or other portions thereof are of interest to more than one groups of forest users and dwellers, including humans and fauna (Cummings, 2013), distribution and distance from the center of Amerindian communities was studied to address two overarching questions:

1. Can the proximity and presence of particular tree and palm species be attributed to the activities of indigenous peoples?
2. Is there a relationship between plant species that provide key ES and distance to an Amerindian community, that is, as distance increases from the center of communities, is there a decline in the presence of species of most critical economic importance?

2. Methodology

2.1 Study Area

This study was completed in the tropical forest and savannah biome of the Rupununi, Southern Guyana (Read et al, 2011) located between 0° 50’ – 4°49’ N and 56° 54’ – 59° 55’ W. Sampling for tree and palm species was completed across an area approximately 48,000km^2 (Figure 1). The study area is the homelands of various Amerindian groups, with the Cariban-speaking Makushi and Arawakan-speaking Wapishiana (Colchester, 1997) the dominant groups in the North and South Rupununi respectively (Figure 1).

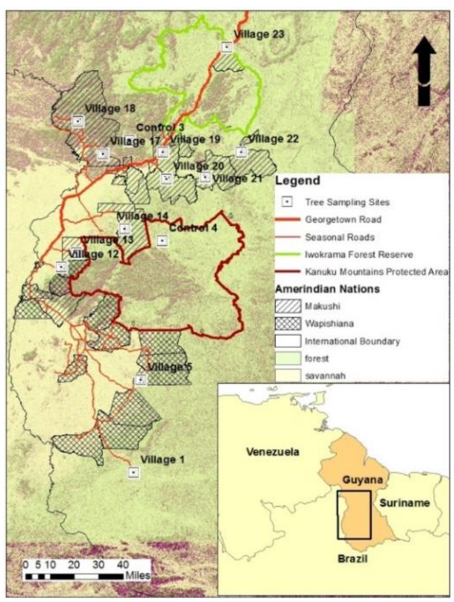

Figure 1. Study area in Guyana

2.2 Spatial and Attribute Data Collection

A total of ninety-two (92) 4-kilometer long, 10-meter wide belt transects (Figure 2) were sampled to inventor trees and palms across fourteen study sites, twelve Amerindian communities and two control sites (Figure 1). Eight (8) transects were sampled at each study site within two zones, a near zone and a far zone, defined as distances of 6 and 12 kilometers from the centre of a study site respectively (Figure 3).

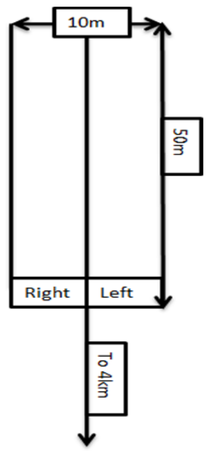

Figure 2. Schematic representation of the 10-meter belt transect for the inventory of trees and palms

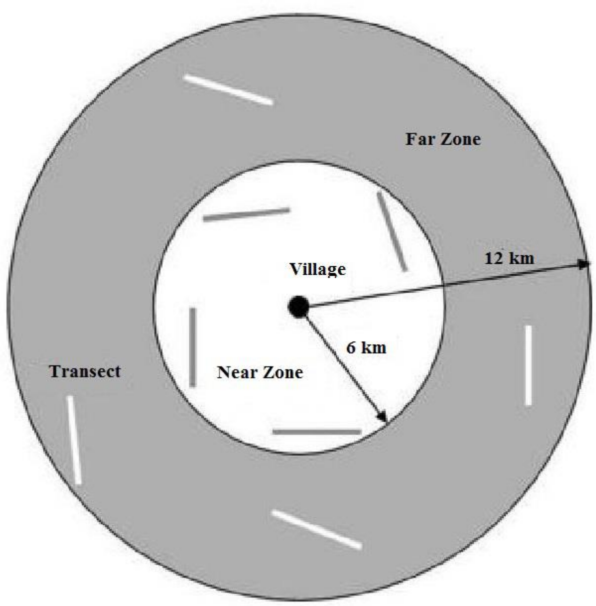

Figure 3. Distribution of transects around a hypothetical village

At the time of sampling, trees and palms were identified into one or more of four economic use classes - wildlife food, commercial timber, traditional uses and no known human uses – based on common names and traditional knowledge. Where two or more economic uses intersected in a single species (or genus if a plant was not identified to the species level), such a plant was defined as multiple-use, with the economic value of plants increasing as the number of ES associated with a species increased. Four multiple-use classes: **wildlife food and commercial timber, commercial timber and traditional uses, wildlife food and traditional uses, and wildlife food, commercial timber and traditional uses,** emerged based on this classification to complement the single-use economic classes.

The 33,457 plants in the sampled comprised 165 species classified in the four multiple-use classes, three single use classes and no known uses (Figure 4), with multiple-use species dominating our sample. Given that indigenous peoples have a strong relationship to their forests, we hypothesize that plants which provide traditional services such as medicines and building materials that are critical to indigenous peoples' livelihood activities will be clustered closer to community centers. In other words, species associated with traditional uses and wildlife food provision were expected to be distributed closer to village centers while plants with timber uses for example, a relatively new endeavor in the indigenous landscape, will be distributed further away.

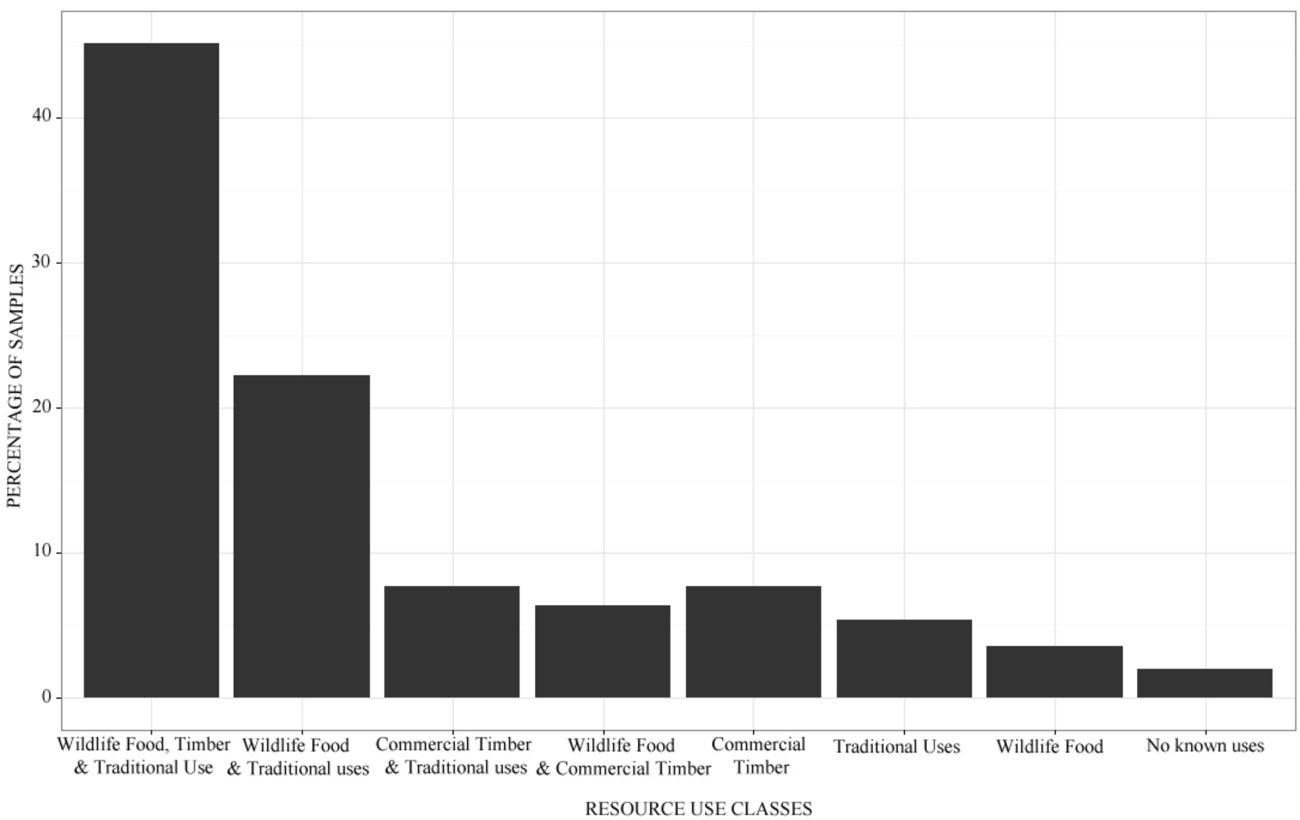

Figure 4. Resource classes and percentages sampled in study area

2.3. Designing the spatial dataset

The database of plants in our sample was disaggregated into multiple-use and single use classes in ArcGIS (Figure 4) as prescribed in Cummings (2013). In addition, the database was disaggregated into individual species. Using an abundance of 100 or more individuals as a criterion for analysis, a total of 73 of the 165 species in our sample were selected across the study area. These 73 species represented all four multiple-use classes and single use classes.

2.4 Calculating average distances to the village sampling locations

The proximity of the 73 individual species to Amerindian village centers and control site was computed using the Near Tool® in ArcGIS. As sampling for plants occurred within 12 kilometers of village centers, a search radius of 12,000 meters was used to compare proximity across plant species (Figure 5).

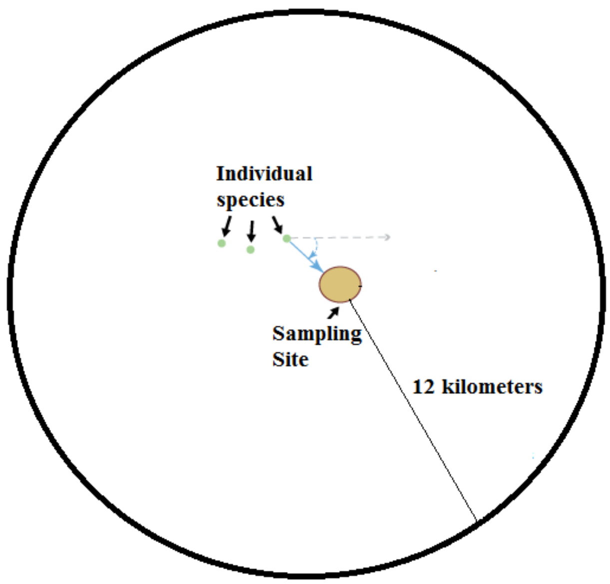

Figure 5. Near distance analysis in ArcGIS for a search radius of 12 kilometres

The distance measures data for each species were compared across the study area relative to village centers (see Table 1 & Table 2) and compared by multiple-use and single-use classes to which they belonged.

2.5 Developing a python tool to simplify analysis

Linear distance measurements to individual plants, that is to a specific attribute within a database, is not currently accommodated in ArcGIS and as such this measurement can only be achieved manually. As such, a Python script was developed based on a loop function to automate the process of measuring distances from village centers to individual plant species in our sample. The steps in the tool development are shown in Figure 6.

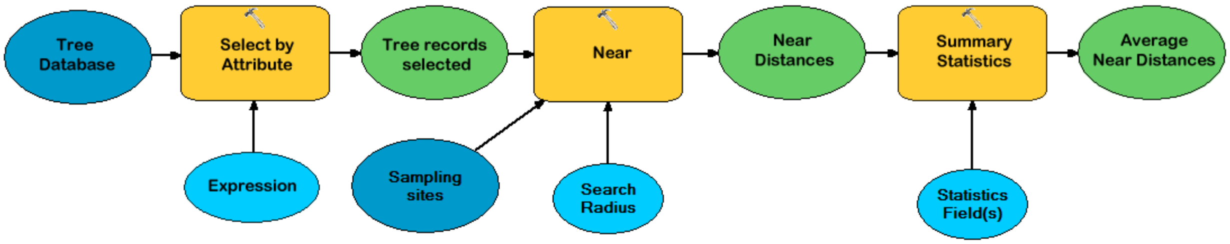

Figure 6. Workflow of the python tool

This tool was innovative in that is allowed us to extract all existing values in a shapefile through the Select by Attribute function in ArcMap. Existing python functions only allow Select function to be modified through selection type parameter. This tool uses a constant SQL expression. Every value corresponds to either the class type (Figure 4) attribute or the distinct species and genus attribute. Once the records based on these values were selected, Near Tool was applied to the selected features (input features) and the sampling locations (near features). The distances were then summarized and the mean value of the distances were taken as the average near distance.

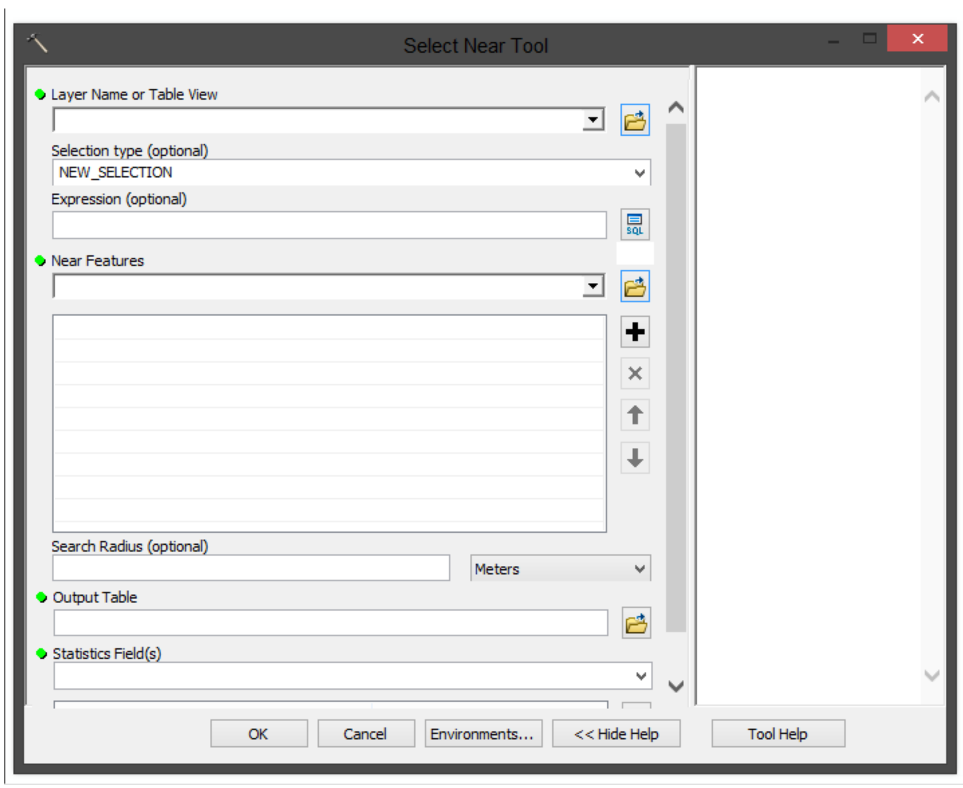

Figure 7. Select near tool developed in ArcMap

These distance measurements then allowed for proximity to villages and control sites to be compared by multiple-use and single-use classes, as well as for individual species.

3. Results

3.1 Distances Relative to Amerindian Village

The distance of plants relative to Amerindian villages and control sites were computed based on the aggregated multiple-use and single-use species classes, but also for the disaggregated form of species with abundance greater than 100 individuals. The distance to individual species were then reconfigured to the classes to which they belonged. These results are summarized below.

Econ Type	Timber	Traditional Use	Wildlife Food	No Known Human Use	Timber & Traditional	Wildlife & Traditional	Wildlife & Timber	Wildlife, Timber & Traditional
Village 13	7476.76	10169.23	9070.19	**5873.78**	7143.18	7485.53	7321.37	7760.69
Village 14	8082.05	9224.05	**7935.34**	7943.44	8040.70	8221.36	8746.74	8088.89
Village 17	8274.54	**3430.09**	7408.23	11843.13	5887.63	8745.74	11423.02	10272.34
Village 18	6396.99	6249.62	**5349.16**	6925.08	6468.55	6715.36	7823.31	7421.32
Village 23	**6379.89**	6912.30	6896.52	7666.54	7298.68	6924.94	6859.97	7100.81
Village 22	6640.32	6848.65	4683.95	5621.97	**4258.73**	6888.79	4761.12	7003.11
Village 21	8059.62	8834.10	8415.58	8270.65	**6894.63**	7637.84	7259.04	7981.00
Village 19	7077.82	7125.18	6330.22	7361.37	7454.43	6599.77	**5767.84**	6964.61
Village 20	8972.45	8823.67	10283.75	8913.41	**7835.57**	8529.70	9448.22	8038.97
Village 12	10430.18	10189.62	9868.09	10218.38	9688.07	**9543.68**	10490.55	10477.05
Control 4	6540.70	6796.66	6069.48	6717.07	5868.36	6273.96	**5732.60**	6792.99
Control 3	7376.02	**6637.14**	6790.70	8067.10	7110.71	7295.15	7868.65	7105.63
Village 5	7888.99	7983.76	8312.87	8750.73	**6292.81**	7199.23	8315.65	8880.99
Village 1	6781.41	7168.90	9170.04	7118.90	7004.00	6946.02	7095.66	**6686.54**
Avg. Dist.	7598.41	7599.5	7613.15	7949.4	**6946.15**	7500.50	7779.55	7898.21

Table 1. Average near distances based on the aggregated economic class types

Aggregated Multiple-use and Single-use Classes

The analysis of the distribution of plants aggregated at the multiple-use and single-use classes level showed that overall plants in the class Timber and Traditional Uses were closest to five Amerindian villages, while Traditional Uses, Wildlife Food and Timber, and Wildlife Food were closest to two villages respectively (Table 1). As expected, no known human use plant species were located the farthest away from village centers.

3.2 Individual species distance measurements and then re-aggregated to classes

Using the 73 species with abundance greater than 100 individuals, it was further revealed that species in the class Timber and Traditional purposes were closest to seven (7) study sites, six (6) Amerindian villages and one (1) control site (Table 2). The red colored values indicate those class types which were closest to the sampling sites. Plants in the Wildlife Food class was found to be closer to three (3) study sites, two Amerindian villages and a control site, as well. Traditional-use class was the furthest away on average and was far away from 4 sampling sites.

Econ Type	Timber	Traditional Use	Wildlife Food	Timber & Traditional	Wildlife & Traditional	Wildlife & Timber	Wildlife, Timber & Traditional
Village 13	7125.26	10726.85	**2774.06**	3921.52	7566.02	3582.65	6107.67
Village 14	8574.75	9065.73	6712.61	**6193.81**	7522.18	8508.05	7391.61
Village 17	5095.59	6297.89	8410.64	4655.33	**3735.17**	7809.74	4060.32
Village 18	6141.15	5915.68	**3833.03**	5243.38	5104.38	4506.19	5550.23
Village 23	**4711.34**	5078.71	4826.56	5573.49	5033.95	5653.96	5942.23
Village 22	5951.74	7003.77	6650.83	5387.47	6973.41	**3866.89**	5945.19
Village 21	7337.04	5413.86	6005.70	**4789.15**	5764.09	5590.98	6005.79
Village 19	7269.65	6619.38	4863.15	**4191.67**	5299.70	5560.59	5761.93
Village 20	7417.37	**4557.51**	4846.72	5278.50	7996.44	4760.50	7286.95
Village 12	8784.35	8399.85	7317.73	**4961.02**	9242.69	8998.06	8214.23
Control 4	6277.70	6238.91	**3376.88**	4654.81	5275.73	6139.73	5655.97
Control 3	6976.26	6954.48	5015.27	**4454.06**	5713.59	7244.19	5745.73
Village 5	7555.42	7709.22	6909.62	**5933.52**	7521.70	7899.42	6625.46
Village 1	7253.07	7478.80	6088.45	7199.75	6838.17	6719.57	**6082.46**
Avg. Dist.	6890.76	6961.48	4137.64	**5174.10**	6399.08	6202.89	6169.7

Table 2. Average near distances based on individual species that had abundance greater than 100 individuals

4. Conclusions

Our results suggest, both when all the plants in the sample are considered at the multiple-use and single-use species level, and by individual species, that plants with traditional uses are clustered closer to communities. Further, we found that species that provide wildlife food services were also clustered around communities. Interestingly, though, and this is a critical point for the sustainability of indigenous peoples livelihood activities, the class traditional uses and timber was the one closes to Amerindian communities on seven of the fourteen study sites, suggesting that should such plants be removed for commercial logging then there will be impacts for traditional activities. In addition, the close proximity of plants that provide food for wildlife to communities is not surprising as most of these wildlife are hunted by indigenous peoples, and the presence of food sources close to villages will facilitating traditional hunting practices.

5. Future work

To test the hypothesis that plants with higher economic value will be distributed closer to village centers, land-use models, in particular Van Thunen's, will be further utilized. Von Thunen's model suggests that a city will be centrally located and would be surrounded by concentric circles that represent how crops are cultivated and economic activities are distributed relative to the city center, which is a radial point.

Von Thunen's model further suggests that a commercial farmer will pick a location for his activities based on transportation and land cost that will allow for profits to be maximized (Figure 5). Von Thunen's model of agricultural land-use has been used by scientists to study the impacts of deforestation in tropical forests (Thomas, 2007) and global trade and production patterns (Venables and Limao, 1999).

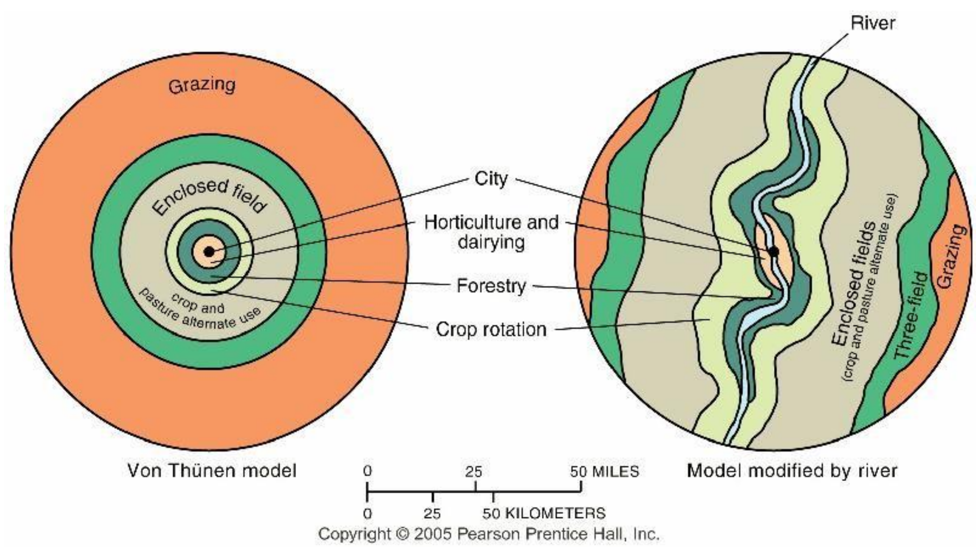

Figure 8. Example of Thunen's model – regular and modified by a river

6. Acknowledgements

Funding for this project was made possible by the US National Science Foundation BE/CNH Grant 0837531. We are grateful to the support and permission to complete this work provided by the people of the Rupununi.

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